Energy changes and reversible reactions

4.6.2.2 · The rate and extent of chemical change · revision notes

If a reversible reaction is exothermic in one direction, it is endothermic in the other, and the same amount of energy is transferred each way. Questions often use the hydrated copper sulfate example and ask you to state the energy change for the reverse reaction.

Key facts

- Exothermic in one direction ⇌ endothermic in the other direction
- hydrated copper sulfate (blue) ⇌ anhydrous copper sulfate (white) + water
- White → blue: exothermic (add water and it gets hot)
- The same amount of energy is transferred in each direction
- Blue → white: endothermic (heat it)
- Decomposing ammonium chloride: endothermic; re-forming it: exothermic

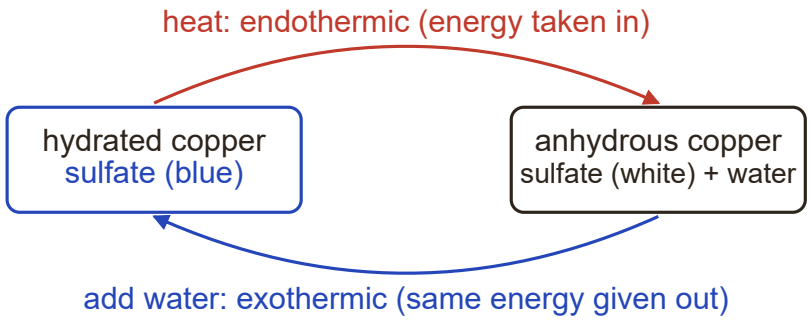
Notes

Energy in both directions

- Recall: an **exothermic** reaction transfers energy to the surroundings, so the temperature of the surroundings rises. An **endothermic** reaction takes in energy from the surroundings, so the temperature falls.
- If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction.
- The **same amount of energy** is transferred in each direction.
- Example: if the forward reaction takes in 30 kJ, then for the same amounts of substances the reverse reaction gives out 30 kJ.
- The energy transferred is proportional to the mass that reacts. If 50 g takes in 12 kJ, then 10 g takes in 12 × 10 ÷ 50 = 2.4 kJ.

Example: copper sulfate

- hydrated copper sulfate (blue) ⇌ anhydrous copper sulfate (white) + water
- 'Hydrated' means containing water; 'anhydrous' means without water.
- **Forward reaction (endothermic)**: heating blue hydrated copper sulfate drives off the water, leaving white anhydrous copper sulfate. Energy must be supplied.
- **Reverse reaction (exothermic)**: adding water to white anhydrous copper sulfate turns it blue again, and the mixture gets hot.
- The energy taken in to remove the water is the same as the energy given out when the water is added back.



The same amount of energy is taken in one way and given out the other way.

Example: ammonium chloride

- Decomposing ammonium chloride into ammonia and hydrogen chloride is endothermic: it only happens while you keep heating.
- So the reverse reaction, where ammonia and hydrogen chloride form ammonium chloride, is exothermic.

How to answer each type of question

State the energy change for the reverse reaction 2 marks **Grade 5**

1. Find the energy change given for one direction.
2. Swap it: exothermic becomes endothermic, and endothermic becomes exothermic.
3. Keep the same amount of energy, and say whether it is taken in or given out.

Example. Nitrogen dioxide forms dinitrogen tetroxide in a reversible reaction.
$2NO_2 \rightleftharpoons N_2O_4$
When 2 moles of NO_2 form 1 mole of N_2O_4, the forward reaction transfers 57 kJ of energy to the surroundings.
Give the energy change for the reverse reaction, when 1 mole of N_2O_4 forms 2 moles of NO_2.

Model answer. 57 kJ (1) is taken in from the surroundings / the reverse reaction is endothermic (1).

Deduce the energy changes from information about a reaction

3 marks | Grade 5

1. If energy must be supplied (heating) to make a direction happen, that direction is endothermic.
2. The opposite direction is then exothermic.
3. It transfers the same amount of energy.

Example. When solid X is heated, it decomposes into gases Y and Z. When the gases cool, they react to form X again.
$X \rightleftharpoons Y + Z$
(a) Is the forward reaction exothermic or endothermic? Give a reason.
(b) Describe the energy change of the reverse reaction.

Model answer.

(a) Endothermic (1), because energy (heat) has to be supplied to decompose X (1)

(b) It is exothermic and transfers the same amount of energy to the surroundings (1)

Describe and explain the copper sulfate reaction

3 to 4 marks | Grade 5

1. Give the observations: the colour change, and the temperature change when water is added.
2. Say which direction is endothermic (heating, blue to white) and which is exothermic (adding water, white to blue).
3. Say that the same amount of energy is transferred in each direction.

Example. A student heated blue hydrated copper sulfate crystals in a test tube until they turned white. After letting the tube cool, the student added a few drops of water to the white solid.
Describe what the student would observe when the water was added, and explain the energy changes in both steps.

Model answer. The white solid turns blue (1) and gets hot / the temperature rises (1). Heating hydrated copper sulfate is endothermic, because energy is taken in to remove the water (1). Adding water is the reverse reaction, which is exothermic and gives out the same amount of energy (1).

Don’t lose marks

- Saying the reverse reaction transfers a different amount of energy. It is exactly the same amount.
- Mixing up the colours: hydrated copper sulfate is blue, anhydrous copper sulfate is white.
- Saying both directions are exothermic because 'heat is involved' in both.
- Describing only the colour change when asked what you would observe on adding water. Also say it gets hot.

More tips

Memory tricks

- Flip the reaction, flip the energy change: exo becomes endo, and the amount stays the same.
- Blue to white needs heat; white to blue gives out heat.
- If you have to keep heating to make it go, that direction is endothermic.

Exam technique

- Use the words 'exothermic' and 'endothermic' and say which direction each one applies to.
- When giving the energy change for the reverse reaction, state both the amount and whether energy is taken in or given out.
- Use 'hydrated' and 'anhydrous' correctly: examiners expect the right names with the right colours.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Recall what exothermic and endothermic mean

Exothermic reactions transfer energy to the surroundings; endothermic reactions take in energy from the surroundings.

Grade 4

Know the reverse has the opposite energy change

If the forward reaction is exothermic, the reverse reaction is endothermic, and the other way round.

Grade 4

Give the energy change for the reverse reaction

Same amount, opposite direction: e.g. forward takes in 50 kJ, reverse gives out 50 kJ.

Grade 5

State that equal energy is transferred each way

The energy taken in one way is exactly the same as the energy given out the other way.

Grade 5

Describe the copper sulfate reversible reaction

Heating blue hydrated copper sulfate gives white anhydrous copper sulfate and water; adding water reverses it.

Grade 5

Link the colour changes to energy changes

Blue to white takes in energy (endothermic); white to blue gives out energy (exothermic).

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